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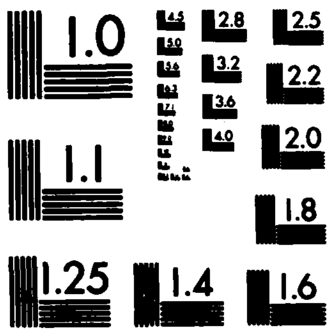


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# MARINE ENVIRONMENTAL ACOUSTICS

FINAL REPORT

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
CODE 500
Contract: N00014-80-C-0219

Total Award: $1,868,636
1 November 1979 through 15 December 1982

Principal Investigators
Kenneth M. Watson and Victor C. Anderson



1 August 1983

MPL-U-51/83



MARINE PHYSICAL LABORATORY
of the Scripps Institution of Oceanography
San Diego, California 92152

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Marine Environmental Acoustics Program of the Marine Physical Laboratory can be best typified as one with an experimental emphasis, addressing the acoustic, hydrodynamic, magnetic environments of the ocean. In particular we are concerned with understanding the interaction of the environment with the Navy's needs in undersea detection, localization and communication.

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# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Coherent Recombination of Sediment Borne and Water Path Acoustic Signals
(Contract Period: November 1, 1979 through October 31, 1981)

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Scripps Institution of Oceanography
San Diego, California 92152

This program has the dual, long-term objectives of: (1) characterizing low frequency acoustic attenuation in and propagation through thick sediment sections and (2) investigating to what degree an array near the sediment-water interface could be matched by appropriate signal processing to these two significantly different paths with the goal of coherently recombining the total acoustic field which is available.

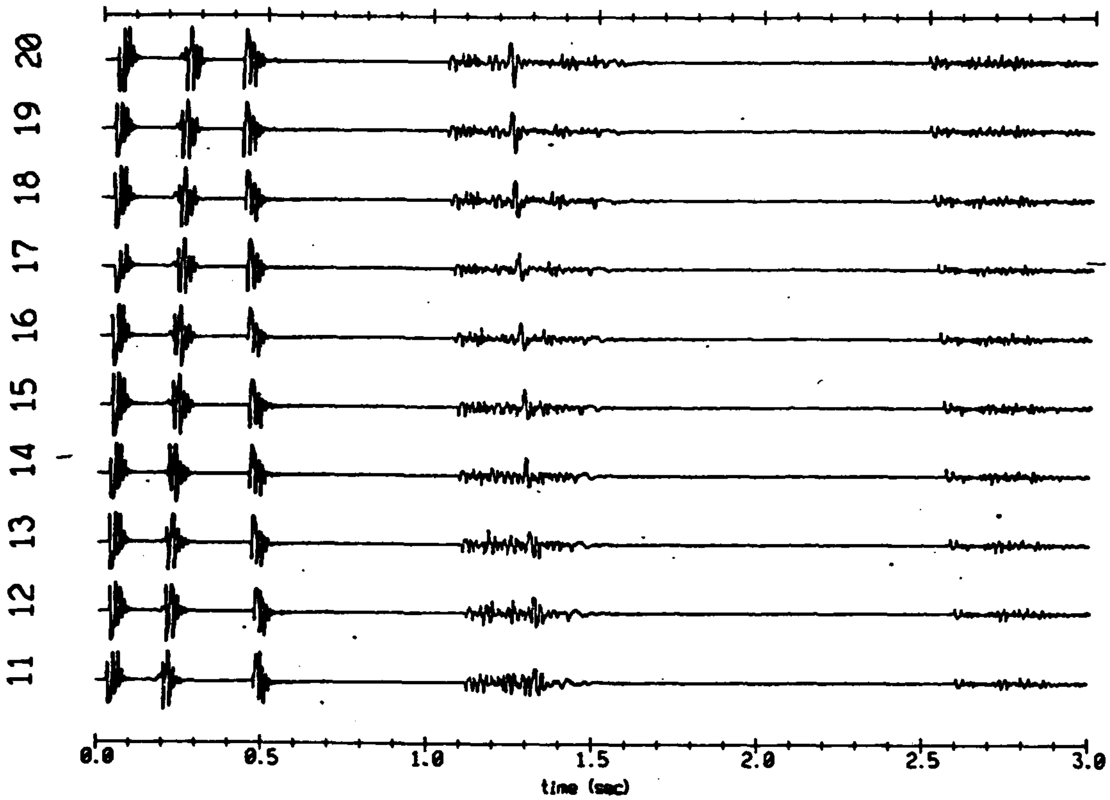
Both the water layer and bottom sediment act as transmission media for acoustic signals. Since attenuation and velocity of sound are quite different in sediments than in the water column, the observed properties of the sediment and water borne paths are expected to be quite different. These differences include differences in amplitude, frequency content, arrival time and angle.

In April 1981, the Marine Physical Laboratory (MPL) conducted an experiment investigating acoustic signal propagation in thick sediments. The experiment involved the deployment of a 20-element array from FLIP in an area of thick sediments (2.5 km) on the Monterey Fan. The hydrophone array which had equal sensor spacing and a total aperture of 500 m was placed at mid-depth in the 3 km deep water column. Both shallow (300' SUS) and deep (6000' SUS + 252# TNT) explosive sources were utilized.

The data which has been worked with thus far is from the deep shots. The accompanying figure illustrates the excellent quality of the data via plots of the time series from hydrophones 11-20 for one of the shots. Also provided are plots of the ray paths corresponding to the first three arrivals. First, an estimate of the range and depth of each shot detonated needed to be derived. Having localized

the shot detonations, our work to present has focused on the actual bottom interacting paths. The next step in the analysis is to derive via inverse theory the sediment sound speed profile. In order to do so, a sediment travel-time versus range summary of the data has been derived. Our approach has been to trace the ray paths of interest, both from the array and from the shot detonation point, down to the water-sediment interface. Thus, the travel-time and horizontal range corresponding to the water pathway are determined and the corresponding figures for the sediment portion can be calculated (after some first order corrections for bottom topography).

Significant accomplishments in this program to date include: (1) successful completion of an experiment on the Monterey Fan, (2) derivation of an accurate estimate of the range and depth of each shot detonation, and (3) completion of a sediment travel-time versus range summary of the data.


20
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18
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11
0.0
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1.0
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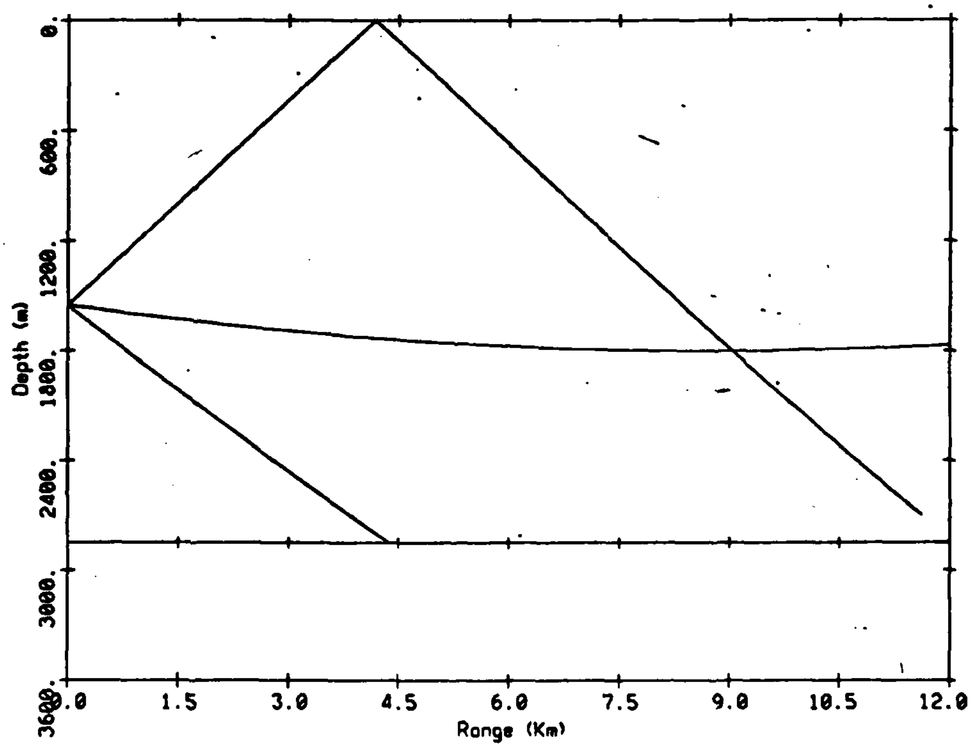
time (sec)


0.
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1200.
1800.
2400.
3000.
3600.
Depth (m)
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
Range (Km)

# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Mixed Layer Dynamics
(Contract Period: November 1, 1979 through December 31, 1982)

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During the three years in which this contract was operative, significant progress was made in the development of Doppler sonar technology for oceanic remote sensing. By late 1979 a successful prototype Doppler sonar has been developed and three duplicates had been produced. These were mounted on the Research Platform FLIP with each sonar aimed in a different direction. The objective wsa to achieve a three-dimensional internal wave array to determine the directions of wave propagation.

In May 1980 the multiple sonar array was used at sea to collect an extensive data set. The quantity of useful information obtained was enormous. The scientific analysis of this data set is still progressing actively. Several publications have been completed.

While analysis of the 1980 data has progressed, preparations for a second data collection cruise have begun. The objective of the second effort is to monitor the large scale turbulent flows in the mixed layer and to observe their relationship to the internal wavefield below and to the wind forcing above. The approach is to shoot very narrow sonar beams horizontally through the mixed layer just below the surface of the sea. The technical challenge is to construct sonars with beam patterns which are "clean enough" that sidelobe returns echoing off the sea surface do not dominate the volume scattering from the main beam.

Using the existing acoustic components from the 1980 experiment, a pair of exceptionally narrow beam transducers were developed under the terms of this contract. Also, four smaller sonars were fabricated. These four sonars pointed 45° downward, to monitor the internal wavefield below the mixed layer. A major effort was also made to improve the azimuthal stability of FLIP. When in the vertical

posiIP's axial orientation was controlled by a hydraulically poweellor mounted approximately 15 feet off the centerline of the ith support from the contract, the orientation system was improoth power and efficiency. The 25 horsepower motor which drovstem has been replaced by a 60 horsepower motor. The 24 inchr propellor was replaced by a 48 inch ducted fan. Compf the thruster system is being supported by the Office of Navach Code 220.

ɔff of these technical developments will be in the Fall of 1983ɜ second Doppler sonar data collection cruise will occur. The ı will be in conjunction with the Office of Naval Research MILDiment. FLIP will rendezvous with two other research ships apprᵧ 500 miles off the California coast. It is hoped that twenıays of continuous data will be collected. The result of thisɜhould greatly increase our understanding of the turbulent mixeand its relationship with motion above and below the sea.

# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Multipath Propagation Observations
(November 1, 1979 through October 31, 1980)

F. H. Fisher

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During the above time period work was carried out on all of the objectives as outlined in our proposal for FY 80 (UCSD 1584) with one exception; namely, that because a storm ended our radial run, we were unable to complete a tangential run. Analysis of the CONTRACT V data extended throughout FY 80 and into FY 81. The results were published in a Journal of Underwater Acoustics article.

Reference

1. Williams, Robert Bruce, Fisher, F. H. Long-Range Vertical Arrival Structure (U). U.S. Navy Journal of Underwater Acoustics, Vol. 31, No. 4, pp. 417-438 (October 1981). (CONFIDENTIAL)

# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Vertical Arrival Structure
(November 1, 1980 through October 31, 1981)

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The proposed work for FY 81 (UCSD 1934) was modified considerably due to a retroactive cut in our SEAS funding, which eliminated the proposed experiment in a mildly bottom-limited region. This in turn eliminated our proposed analysis of the bottom-limited paths we obtained on CONTRACT V. Continued analysis of noise and quantitative analysis of pattern recognition characteristics of CONTRACT V data resulted in an article published in the U.S. Journal of Underwater Acoustics.

We did commence studies as to how to eliminate system noise in the 20-element analog array and how to design an improved digital array with more channels. This work ultimately resulted in an ONR committment to help fund a new digital array in FY 82 in conjunction with array upgrade funding from SEAS.

## References

1. Williams, Robert Bruce, Extracting Important Target Information from Vertical Structure (U). U.S. Navy Journal of Underwater Acoustics, Vol. 32, No. 4, pp. 367-374 (October 1982). (CONFIDENTIAL).

2. Williams, R. B. and Layton, M. R., A Technique for Source Depth Discrimination in Shallow-Water Propagation Conditions (U). U.S. Navy Journal of Underwater Acoustics, Vol. 32, No. 3, pp. 249-252 (July 1982). (CONFIDENTIAL)

# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Sound Propagation Through Thick Sediments
(November 1, 1979 through October 31, 1980)

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During the period of this contract, the primary work of the group was the determination of fine-scale variations of sound velocity with depth in thick sedimentary sections of the seafloor, and the determination of attenuation of sound waves as a function of depth in the same area. In the process of doing this we developed some new hardware and techniques for study of the seafloor. One item of hardware was a long (6 km) towed near-surface array and a digitization system to go with it; another item was a set of inexpensive moored telemetering/recording buoys for seismic work; a third was a set of free-fall recording ocean bottom hydrophones, which record signals over a wide dynamic range and return to the surface at a preset time. The second and third sets of equiment have been highly successful, and with them we have made observations of sound-wave arrivals from deep explosive shots to deep and shallow receivers. These observations have provided data on sound velocity variations as a function of depth in the sea floor over ranges of depth that are difficult to study using shallow sources or receivers.

The best set of data, from the central portion of the Bengal Fan has provided a precise determination of velocity with depth, and a determination of attenuation as a function of depth, showing that the attenuation coefficient, high near the surface of the sediments, decreases rapidly at depths near 600 meters and drops to a value in the deeper part of the sediment section that is little, if any, greater than in hard rock sections.

The depth at which the attenuation begins to drop is approximately the same as the depth at which the gradie[illegible] of velocity with depth begins to drop from its high initial values to a lower rate of increase, leading one to believe that the effe[illegible] [illegible]arily one of consolidation -- [illegible] at which grains in the sediments are in firm con[illegible]ct due [illegible] the weight of the overlying material.

# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Residual Noise
(Contract Period: November 1, 1980 through October 31, 1981

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The long range purpose of this program, begun in FY 78, is to develop a capability for study of the low frequency (< 500 Hz) "residual" acoustic noise field upon which the noise from distant shipping is superimposed. This residue is the background which will limit truly high performance passive systems, and at least a part of it will become the principal background in the event of drastic control of shipping which could occur in times of emergency.

Study of the "residual" noise field also implies study of fine-scale azimuthal and statistical structure of low-frequency noise, since it is with high azimuthal resolution that one should be able to discriminate between noise from individual ships and the background noise from intervening sectors.

To be a flexible research tool, such a capability needs to be mobile (so it can be used at a variety of locations, independent of bottom topography), variable in depth (in order to investigate depth dependencies) and long enough to resolve ships separated by reasonable distances an ocean away. Given generalized ocean basin shipping distributions, an array about 20 wavelengths long should be adequate. Since one expects the residual noise field to be down as much as 30 dB below ambient shipping noise, sidelobe rejection must also be good, and self-generated noise levels must be well below ambient levels. This implies a well-filled array and very quite support vessels. For an array operating 100 and 200 Hz, about 400 elements are needed with a length of about 3 km.

Our approach to this problem has been the incremental development of a capability for handling and localizing a long horizontal array. Deployed and controlled from FLIP in a 3-point moor on one end,

attached to a buoyant line crawler anchored to the bottom on the other navigated by means of transponders, the array would be capable of variable depth operation from a stable and very quiet support platform. Construction and initial testing of the line crawler has already been completed.

Design of the multi-element braided Kevlar array has been completed; selection and testing of hydrophones and in-array circuitry components has been partially completed; and the design requirements for the shipboard array research/recovery system has been defined.

# MARINE ENVIRONMENTAL ACOUSTICS

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
Code 500
Contract: N00014-80-C-0219

## Vertical Directional Noise Properties
(Contract Period: November 1, 1979 through October 31, 1980)

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During May of 1978, vertical directionality data were collected off the Southern California coast in deep water. A 20-element array was positioned at five different depths in the water column, and data collected in the 10-50 Hz region. The data recovered from this experiment have proved to be excellent. Primary processing of this data was completed during FY 80.

During April of 1979, the May experiment was essentially repeated, with the array and data collection reconfigured to collect data in the 50-400 Hz region. In addition, data were collected from sound sources aboard FLIP, to permit us to accurately measure hydrophone positions and motion.

We now have two data sets which span the frequency range from 10-400 Hz. During FY 80 we began the processing of the April 1979 data, with particular emphasis on deviations and coherence statistics, both for individual sensors and beams. Comparisons between the two data sets have proved very interesting.

Our objective in this work have been twofold. First, an understanding of depth, directional and statistical properties of the ambient noise field provides critical data for future estimation of low frequency array gain and performance. Second, noise directionality and fluctuation statistics help in isolating and understanding the various factors which control sound propagation and noise generation in the ocean.

The frequency range of our two data sets represent frequencies which are totally ship dominated at the low end, and frequencies which represent a combination of surface and ship generated noise (the

proportion depending on sea state and weather, as well as ship distribution). Our initial results suggest that the low frequency data are characterized by very short and very long term fluctuations. The higher frequency data, with a significant storm- generated component have more intermediate period fluctuations.

A first report on findings from this work was published as part of the conference proceedings on Underwater Ambient Noise, 11-14 May 1982, La Spezia, Italy.

Tyce, Robert C. Depth Dependence of Directionality of Ambient Noise in the North Pacific: Experimental Data and Equipment Design. SACLANT ASW Research Centre Conference Proceedings No. 32, Vol. II, Part I, pp. 9-1 thru 9-16 (June 1982).

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